A METHOD OF TEACHING RELATIONAL ANATOMY.*

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For many centuries the science of anatomy has been universally recognized as the foundation for the study of medicine. It is, therefore, evident that the best method of studying and teaching this fundamental subject is a problem of great importance. To anatomy belongs the credit of being the first science to adopt the objective, or laboratory method of study. Anatomists long ago insisted that the only way to gain real knowledge of anatomy is by dissection. The art of dissection has therefore been diligently cultivated for many centuries, and the practical limit of its development was reached nearly one hundred years ago. Indeed, the anatomists of the present day are perhaps inferior in the art of dissection to those of the previous generation. This is undoubtedly due to the increased attention paid in recent years to the related subjects of comparative anatomy and embryology, and to the new world of facts revealed in microscopic anatomy or histology. The effect of these studies has been to revolutionize the science of anatomy, so that its present scope and significance are perhaps better expressed by the more comprehensive term, morphology.

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Fig. 1.—From photograph of head and neck, anterior view. Lines I to XVII indicate where the sections were made. Female subject, age about 60 years. Landmarks are clearly shown.

Yet, with all the time spent in dissection, and in spite of the flood of light thrown upon the subject by recent advances in comparative and microscopic studies, we still fail to accomplish the desired end. The ambition of the student of anatomy is, or should be, the ability to *see through* the body, perceiving in the mind's eye all the structures included therein, and their complicated relations to each other. This ability the student must gain somehow, if he is to achieve real success in medicine or surgery; for upon this knowledge are based both physical diagnosis and surgical procedure.

Bearing this in mind, and also the fact that the average medical graduate is very deficient in his knowledge of anatomy from this standpoint, it must be admitted that there is something wrong with our present and past methods of teaching the subject. Wherein do we fail? The reason, it seems to me, lies in the fact that in all the time we devote to the study of the various branches of anatomy—comparative anatomy, osteology, dissection, descriptive anatomy, histology, embryology, etc.—in all these branches we spend practically our entire time upon the study of the individual organs and organ systems, while practically no time is spent in considering the anatomical relations of these organs to each other, and to the surface of the body. To me it seems clear that so long as this is true, the student's knowledge of anatomy, at least from the standpoint of medicine, must necessarily remain incomplete and unsatisfactory.

This being true, the question arises: What method can we use to study what we may term the relational anatomy of the various organs? Take the liver, for example. How shall we proceed to study the exact spatial relations of the liver to the neighboring structures, such as the stomach, kidneys or lungs; and how shall we determine its relations to the surface of the body? It is evident that the ordinary methods of dissection give us very imperfect knowledge in this regard, for in the very act of dissection we must necessarily remove those surrounding structures whose relations it is so important to determine. There is, I believe, only one way in which relational anatomy can be thoroughly, systematically and satisfactorily studied; and that is by means of sections made in various planes

Fig. 2.—Lateral view of the head and neck, photographed from the same subject as Fig. 1.

Fig. 3.—Posterior view of the head and neck. Photograph from same subject shown in Figs. 1 and 2.

in the different regions of the body. Only by this method are the organs made visible in their actual spatial relations to each other. This is by no means a new method of investigation. It has long been used in histology and embryology, where objects are too small or too delicate to be studied otherwise. It has also been applied, to a very limited extent, to the gross anatomy in a few special regions of the human body.[1] But on account of certain difficulties in the application of the method, it has never come into general use. The method which I have to present, therefore, while old in principle, is new in its application; since, so far as I am aware, in no other laboratory of anatomy is it made a regular part of the system of instruction.

The plan which I have worked out for instruction in relational anatomy involves the following consecutive steps: 1. Hardening of cadavers. 2. Study of surface form. 3. Making of sections. 4. Study and drawings of sections. 5. Reference to literature. 6. Written report of results.

Hardening of Cadavers.—Suitable cadavers, selected especially for this work, are injected, not with the usual embalming liquids, but with 50 per cent. formalin, that is, pure formalin (40 per cent. formaldehyde) diluted with equal volume of water. I inject about one gallon, or more if possible, of this liquid into the arteries, usually through the common femoral. This may be followed in a few hours by a second colored injection mass, if desired. Within a few days all the softer tissues of the body become thoroughly hardened. Every organ is thus fixed perfectly in the exact shape and position it occupied during life. Sections may be made at any time after one week. If the cadaver is to be kept some time before using, all that is necessary is to apply vaselin to the skin and wrap with oil muslin bandages to prevent drying. The cadaver will then preserve perfectly, at any temperature, for an indefinite time.

Study of Surface Form.—For the work in relational anatomy, the class—which has previously completed

1. Braune, Macewen, Dwight, and others, have made sections for the investigation of relational anatomy, chiefly by the freezing method.

Fig. 4.—From photograph showing horizontal section through the head, viewed from above, at the level indicated by reference line III, in Figs. 1, 2 and 3. Section passes through the frontal, temporal, and occipital lobes, and the Island of Reil. *s*, Scalp; *c*, cranium; *d*, dura mater; *p*, pia mater; *fs*, frontal sinus; *f*, falx cerebri; *sl*, sup. longitudinal sinus; *il*, inferior longitudinal sinus; *ac*, anterior cerebral arteries; *br*, branches of middle cerebral arteries; *r*, Island of Reil; *f*, fornix; *cc*, corpus callosum; *cp*, choroid plexus in lateral ventricle; *mc*, middle commissure (in 3d ventricle); *pc*, posterior commissure; *ot*, optic thalamus; *ic*, internal capsule; *nc*, nucleus caudatus; *nl*, nucleus lenticularis; *cl*, claustrum.

its dissections by the ordinary method—is divided into groups of two, who work together. Two are assigned to the head and neck, two to the thorax, two to the abdomen, and two to each arm and leg. The first thing that each student does is to make a very thorough study of the surface form of the region to which he is assigned. Special stress is laid upon the landmarks, whose relations to the underlying structures are of great importance. The student makes careful measurements, and records his observations in a note-book kept for the purpose. A mounted skeleton, an Auzoux manikin, and various other models are at hand for comparison.

At this point, photographs are taken showing different views of each region. A set of these photographs is supplied to each student, and they serve a double purpose. In the first place, they furnish an exact picture record of the surface form; and secondly, by means of reference lines drawn later in ink, they serve to indicate the exact level and plane of each section taken. This is a very important feature. In case the photographs were not obtainable, it would be necessary to make very careful outline drawings, upon which the landmarks and reference lines would be shown.

Making of Sections.—Having carefully studied the surface form, and having a record of his observations in notes and photographs, the student now proceeds to cut sections through the body in the desired planes. As soon as made, the sections should be thoroughly washed with water, taking care not to displace any organs. Blood-clots, fecal material, excess of formalin, etc., are thus removed. Cross sections of the extremities are best made at definite intervals, every half-inch or inch. In the head, the sections need not be more than one-fourth inch apart. In the trunk, sections should be somewhat thicker. I have found that it facilitates the handling of sections, and especially the problem of determining the exact level of a given structure, if the sections in the trunk region be made to pass through the intervertebral disks. Then each slice corresponds to the body of a vertebra. It is remarkable how well sections made by this method will hold together, even when they pass through the intestines. Occasionally a piece becomes loose or de-

Fig. 5.—From photograph showing horizontal section, viewed from above, through the head at the level indicated by line IV in Figs. 1, 2 and 3. This section passes through the temporal and occipital lobes, and the upper part of the orbital cavity. *s*, Scalp; *c*, cranium; *m*, temporal muscle; *d*, dura mater; *f*, falx; *t*, tentorium; *sl*, sup. long. sinus; *il*, inf. long. sinus; *of*, orbital fat; *e*, ethmoidal cells; *fs*, frontal sinus; *cg*, crista galli; *ob*, olfactory bulb; *af*, anterior fossa; *ic*, internal carotid; *cp*, choroid plexus of lateral ventricle; *cq*, corpora quadrigemina; *aq*, Sylvian aqueduct; *sn*, substantia nigra; *cr*, crusta; *tg*, tegmentum; *b*, cerebellum.

tached, but it is easily secured in place by a stitch of thread. In the head and trunk, and a few special regions, besides cross sections, coronal and sagittal sections are also necessary. Wherever possible, consecutive sections are left attached to each other at one edge by the skin. The sections are made with a long butcher knife and an ordinary butcher's saw (for bones). If the tissues are thoroughly hardened, the sections are easily and smoothly made.

In this connection, I may remark that this formalin method offers several advantages over the method of frozen sections. No freezing is necessary; the sections are made more easily and smoothly; and, finally, they do not thaw out and become loose or flabby upon handling. This method is also superior to all embedding methods, since not only the surfaces of the sections, but also the structures between, are accessible for examination. In fact, it combines the advantages of dissection with those of plane sections.

In some cases it is advantageous to *combine* the formalin and freezing methods by first hardening the cadaver thoroughly with formalin, as above outlined, and then making the sections by the freezing method.

Dr. Terry[2] has suggested that the bones be decalcified with acids, thus avoiding the use of a saw. This is perhaps admissible in the head region, where dense skeletal parts are so closely related to delicate organs; but elsewhere, I consider it desirable for the student actually to saw through the bones upon reaching them. The location and physical characters of the skeleton are thereby more firmly impressed upon his mind. Even through the head region, as the accompanying figures show, excellent sections can be made without decalcification, which is therefore necessary only when very thin sections are desired.

Study and Drawing of Sections.—After the sections are cut, the student begins the most important part of his work, viz., the study of the sections. Every structure which appears in each section must be identified, every nerve and blood-vessel followed. The position of the various organs with respect to each other, and

2. Proceedings of the Association American Anatomists, Washington, D. C., 1900.

Fig. 6.—From photograph showing horizontal section, viewed from above, of the head at level indicated by line V in Figs. 1, 2 and 3. Section passes through temporal and occipital lobes, and just above the center of the eyeball. *s*, Scalp; *tm*, temporal muscle; *c*, cranium; *n*, nose; *f*, falx; *sl*, sup. long. sinus; *il*, inf. long. sinus; *t*, tentorium; *cb*, eyeball (retina sbrunken); *of*, orbital fat; *on*, optic nerve; *e*, ethmoidal cells; *s*, sphenoidal cell; *ic*, internal carotid; *pt*, pituitary body; *b*, basilar artery; *p*, pons varolii; *aq*, aqueduct of Sylvius; *cb*, cerebellum.

to the surface, must be carefully observed and recorded in a note-book. The sections are studied first separately, and later collectively, by placing them together in their natural order. Finally, in order to impress the relations more strongly upon the student, he is required to make a careful outline drawing of each section. We have adopted for this work a method of drawing which makes it easy and at the same time very accurate. A piece of plate glass in an open frame is laid directly upon the section which is to be drawn. Then, by means of pen and India ink, the outlines are traced, showing all the organs visible through the glass, in their exact relations. When the ink is dry, a sheet of drawing paper or bristol board of the proper size is placed in the frame and fastened by an inner frame behind the glass which contains the ink outline (See Fig. 8). Upon holding up the frame toward the light, the ink outline shows through distinctly, and can readily be traced with a pencil upon the drawing paper. At night the drawings are readily transferred by placing the frame over an electric light. The principle of tracing upon glass was suggested by one of my students, the drawing frame being an invention of my own. The most difficult and important part of the drawing, an accurate outline of the various structures, is now upon the drawing paper. The pencil outline is retraced with ink, and the details are readily filled in with ink, water colors, etc., according to the taste of the individual student. These drawings are very highly prized by the students, and, indeed, form a valuable set of plates for future reference.

Every structure appearing upon these drawings is, of course, carefully labeled, and the reference line on the photograph showing the plane of the section is also indicated by numbers.[3] For the sake of uniformity, every drawing should represent the *upper surface* of the section, unless there is a special reason for the contrary. Moreover—and this is a point upon which I insist strongly—every section should be studied and drawn in the position it would occupy if the cadaver

3. A blue print copy of every drawing, and a duplicate of each photograph, are preserved by the laboratory as a record for reference in the future.

Fig. 7.—From photograph of horizontal section, viewed from above, of the head at the level of line VI, in Figs. 1, 2 and 3. This section passes below the cerebrum, striking the cerebellum middle ear and lower part of the orbit. *ea*, External car; *z*, zygomatic arch; *n*, nose; *of*, orbital fat; *s*, nasal septum; *v*, vomer; *e*, ethmoidal cells; *a*, antrum of Highmore; *s*, sphenoidal cells; *ic*, Internal carotid; *b*, basilar artery; *g*, Gasserian ganglion; *mf*, middle fossa; *mc*, middle ear, showing chain of bones; *mc*, mastoid cells; *ls*, lateral sinus; *ch*, cerebellar hemisphere; *nd*, nucleus dentatus; *v*, vermis; *cp*, choroid plexus of the 4th ventricle; *p*, pons varolii; *VII*, 7th cranial nerve; *VIII*, 8th cranial nerve.

were facing the student, that is, with the *ventral* body wall *nearest*, and the dorsal wall on the further side of the drawing. Some uniform method of position is necessary, both in studying and in drawing, otherwise no clear and permanent mental images can be formed. How could one form any idea of geographical location from maps, if the top of the map sometimes indicated north, sometimes south, sometimes east, and sometimes west? The reason for placing the dorsal side of an anatomical figure toward the top of the page is because that represents (when the drawing is held upright) the typical vertebrate position: dorsal surface upward and ventral surface downward. Since a thorough study of human anatomy is impossible without reference to comparative anatomy, the same standard of position should be adopted for both.

Reference to Literature.—The student has now studied and compared his sections, and finished his drawings of them, but still his task is not completed. He has yet to compare his own work with the results of other investigators. To do this he is required to look up references concerning the relational anatomy of the region in the various books and periodicals in the department library. He takes notes here also, and finds, often to his astonishment, that the authors sometimes disagree with each other, and also with the facts as he *knows* them to be in his own sections. Thus he learns the important lesson that the real source of knowledge is Nature, not books.

Written Report of Results.—Finally, in order to get his knowledge arranged in a systematic way, the student is required to write a report in which he sums up briefly and clearly the results of his own observations, and compares them with the statements found in the literature. The writing of this paper, which is, of course, accompanied by the explanatory photographs and drawings, forms an excellent review of the entire subject, and puts the work of the student in a convenient form for future reference.

Besides the thorough study of one region, according to the method outlined, the student is required to review the remainder of the body from sections already made. Thus he becomes familiar with the more important topo-

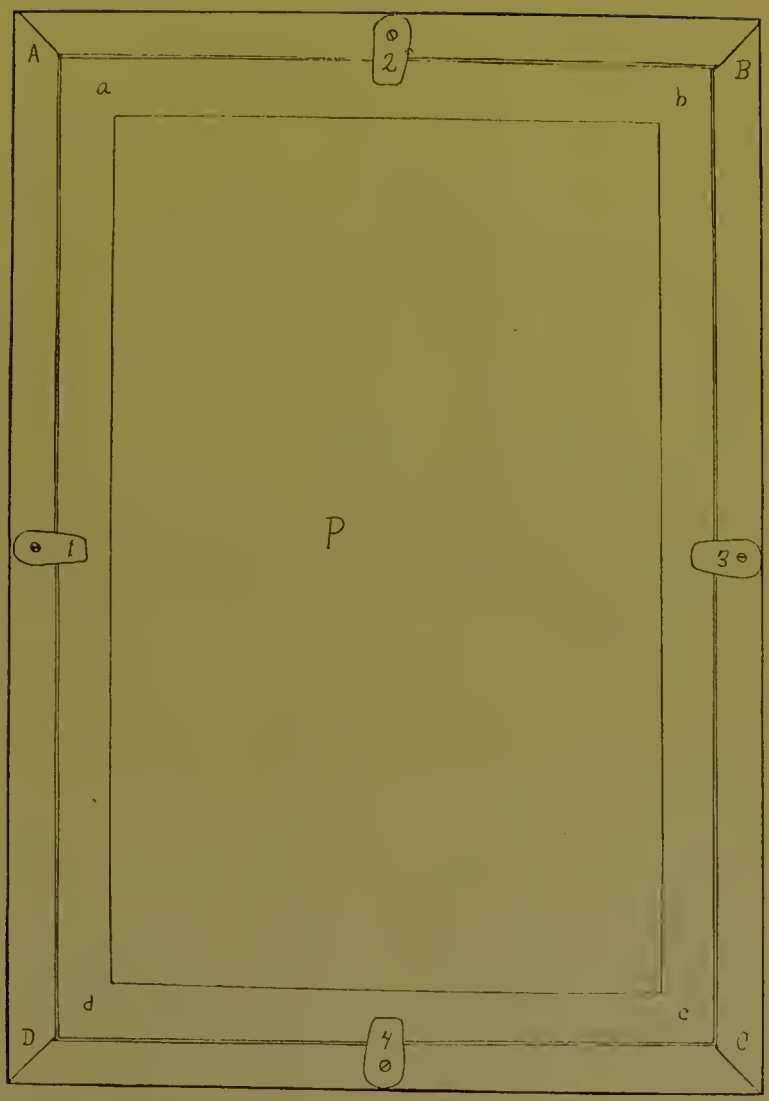

Fig. 8.—A diagram of the Drawing Frame. *abcd,* The *outer* frame, which resembles an ordinary picture frame, in which the glass and drawing paper are pl[illegible] 1; *abcd,* the *inner* frame, which fits into the outer frame [illegible] nd [illegible] glass and drawing paper, holding them firmly i[illegible] 4, wooden "buttons," fastened each by a screw in [illegible] frame, and serving, when turned as in figure, to hold [illegible] frame tightly behind the glass and paper; *p,* space occupied by the glass and drawing paper.

graphic relations of the entire body. More advanced work in topographical anatomy is assigned to students who wish to make a special study of the subject.

In conclusion, allow me to suggest that this method for the study of relational anatomy will be of the utmost value to practitioners who are not located conveniently near anatomical laboratories, but still desire to devote some time to the study of anatomy, especially in its relations to surgery. The method is simple, the apparatus inexpensive, the material keeps indefinitely, and the knowledge gained from a study of the body in this way can hardly fail to be of great practical value. Drying of the sections is the only trouble to be guarded against. This may be prevented, 1, by placing a cloth wet with some slightly antiseptic liquid between every two sections, when not in use; 2, by wrapping the entire part in waterproof cloths; 3, by keeping the sections in an air-tight receptacle, either box, can or jar. Formalin sections dry much less rapidly than alcoholic specimens, however, and can be exposed to the air for two or three hours without damage.

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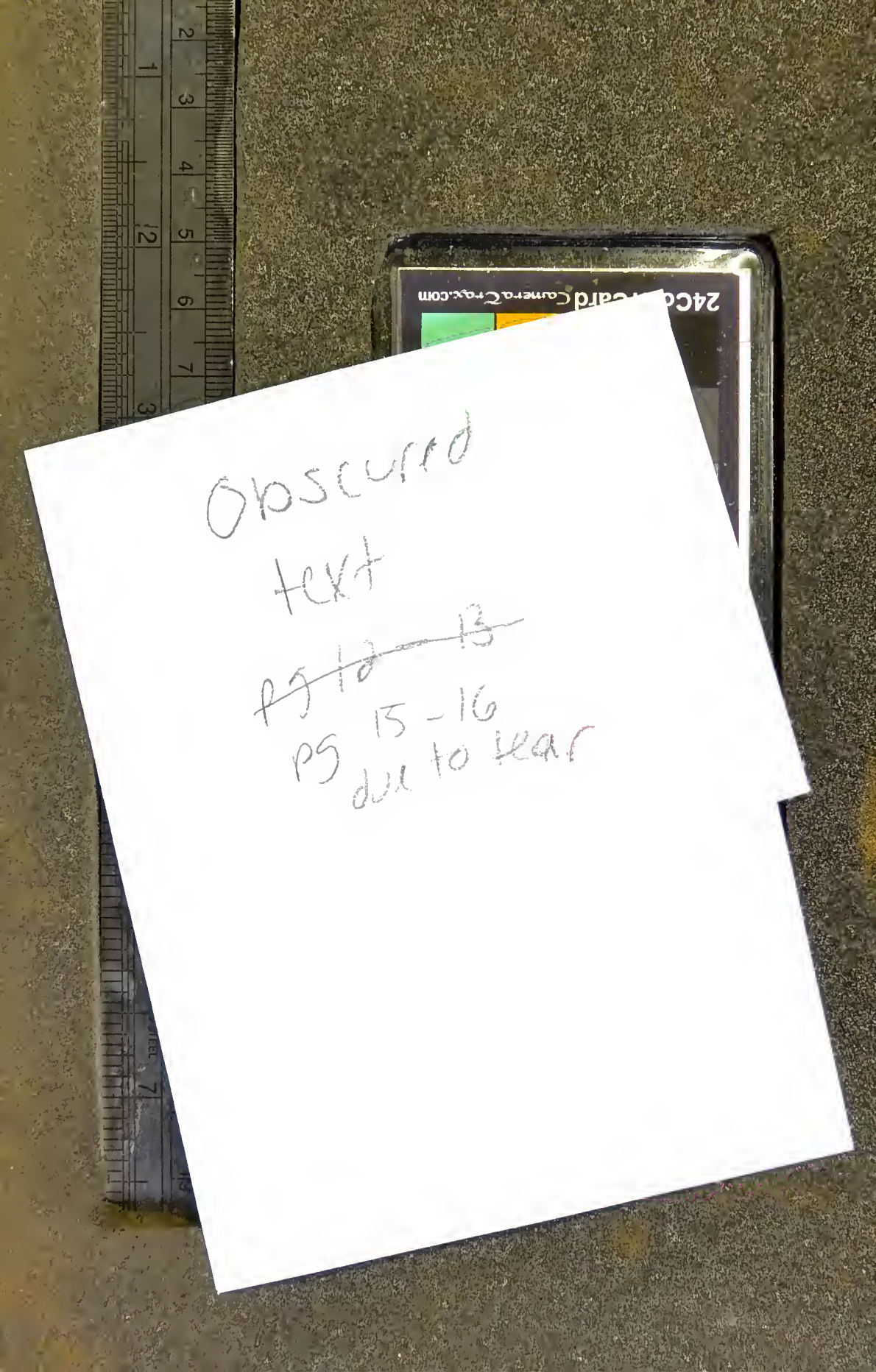
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